CHAPTER 6.—UNDERGROUND HARD-ROCK DUST CONTROL

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In This Chapter

- ✓ Ore pass dust control
- ✓ Drill dust control
- ✓ Blasting dust control
- ✓ Conveyor belt dust control
- ✓ Transfer point and crusher dust control
- ✓ Roadheader dust control

and

- ✓ How much ventilation air to use

This chapter discusses respirable dust control in underground hard-rock mines. These mines use a wide variety of extraction methods, but they have many common dust sources and dust control needs. Ore passes, drills, blasting, conveyor belts, transfer points, crushers, and load-haul-dump operations can be major sources of dust. Roadheaders, which are sometimes used in hard-rock mines, produce dust in large quantities. For the most part, dust in hard-rock mines is controlled with ventilation air, water sprays, and dust collectors. It is also important to prevent dust from getting into the air in the first place. Good dust control practices will reduce overall mine ventilation requirements.

> **Lack of maintenance is the main source of dust problems in hard-rock mines according to Rodgers [1974], who conducted a dust survey of hard-rock mines several decades ago. Rodgers found that spray systems had clogged sprays, dust enclosures had improperly fitted skirts, and ductwork was plugged and had leaks. Today's mines have better maintenance programs (we think), but when dust levels are high, maintenance is still the first topic to address.**

The Mining Association of Canada [MAC 1980] and Knight [1980] provide good general information about hard-rock dust control. For conveyor belt dust control, Goldbeck and Marti [1996] and Swinderman et al. [1997] are valuable sources of information.

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ORE PASS DUST CONTROL

Falling rock moves air. That's the ore pass dust problem in a nutshell.

Ore and waste passes (figure 6-1) produce large quantities of airborne respirable dust. The broken rock delivered to the passes contains a considerable amount of attached dust from preceding operations such as blasting and loading. The grinding action on the rock as it falls down the pass produces even more dust. However, the main problem is that the falling rock entrains air, producing a powerful "piston effect" that generates pressure surges of dusty air.

Good ore and waste pass design can help to relieve these pressure surges. For example, if the ore and waste passes are located near each other, connecting them on several levels will relieve the pressure. Also, dusty air in the passes can be discharged into a return airway [Marshall 1964; Pullen 1974]. The Mining Association of Canada [MAC 1980] recommends exhausting sufficient air from the ore and waste pass system to indraft 200 ft/min air velocity at all leakages, assuming that one tipping location is open continuously. Discharging this air into a return airway eliminates the need to install a dust collector.[3]

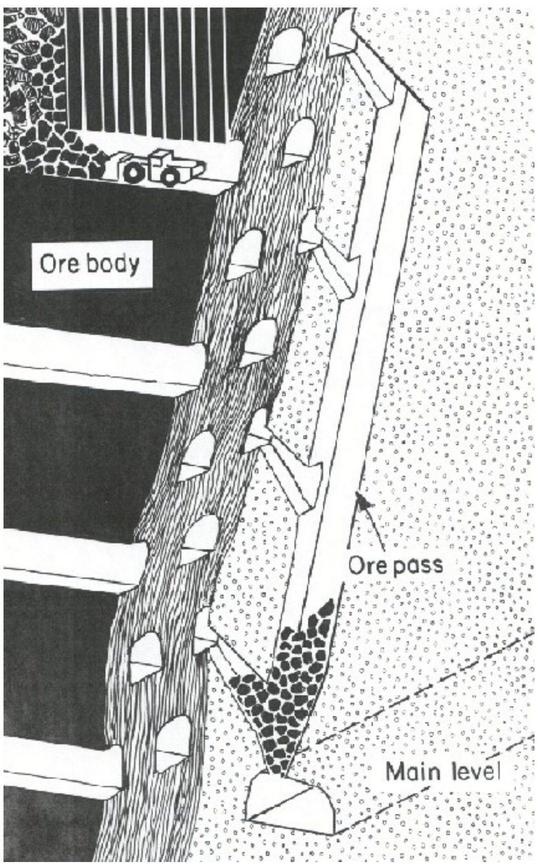

Figure 6-1.—Ore pass adjacent to steeply dipping ore body. ***(Courtesy of the Society for Mining, Metallurgy, and Exploration (SME) (www.smenet.org).)***

No matter what the ore and waste pass design, a critical step in dust control is to prevent its escape and dispersal into working areas by confining dust within the passes. This confinement can be accomplished by a system of stoppings and airtight doors over the ore and rock pass tipping locations. However, since some leakage from these doors is inevitable, another approach to dust control at tipping locations is to isolate them from travelways. This isolation is accomplished by locating the tipping locations in short, dead-end (stub) headings that have local exhaust dust collection systems.

Dust from ore and waste passes will be reduced if the rock is thoroughly wetted before delivery to the tipping site. More water can be added at the tipping site by spraying the rock as it falls into the pass. However, too much water at ore passes can be

[3]Dust collectors located underground must be able to handle high-humidity air and possibly some condensation.

objectionable for many reasons. These include (1) an adverse impact on crushing and milling; (2) accumulation of a large quantity of water on top of the material in the chute, which creates a hazard for workers on the lower levels; and (3) plugging of chutes caused by water-softened clay minerals.

Ore pass dust control is addressed by ILO [1965], Geldenhuys [1959], Kneen [1959], Gray et al. [1961], and Foster [1965]. Ore pass design has been discussed by Hambley [1987]. An extreme case of ore pass pressurization caused by falling material has been discussed by McPherson and Pearson [1997].

DRILL DUST CONTROL

Good drill dust control requires good maintenance.

Drill dust is suppressed by water injected through the drill steel, which has been a common practice for many years [ILO 1965]. Usually, respirable dust is reduced by 95% or better [MSA Research Corp. 1974]. This does not, however, prevent dust from entering the air during the initial collaring period as the drill hole is started. Various means have been tried to prevent the escape of dust during collaring. These range from simple handheld sprays to elaborate types of suction traps around the end of the drill steel. None of these are very efficient.

Drills powered by compressed air are much less common than in the past, eliminating the dust problems associated with their use. For example, if some of the compressed air operating the drill leaks into the front head of the drill and escapes down the drill steel, it will cause dry drilling and carry dust out of the hole. Compressed air escaping through the front-head release ports will atomize some of the water in the front head. This atomized water evaporates quickly and, if the water is dirty, many dust particles will remain in the air [Sandys and Quilliam 1982].

MSA Research Corp. [1974] has listed the factors that can lead to high dust levels on drills. Many result from lack of proper maintenance. These are failure to use water, inadequate quantities of water, plugged water holes in the drill bit, dull drill bits, and dry collaring.

BLASTING DUST CONTROL

Water and ventilation are necessary, but the key to reducing dust exposure is blasting off-shift.

Water is important in controlling dust generated by blasting. The area surrounding the blast (walls, floor, and back) should be thoroughly sprayed beforehand. This precaution will prevent dust settled out during previous operations from becoming airborne. A uniform rock moisture content[4] of only 1% greatly reduces dust compared to dry rock [Quilliam 1974]. However, since it is difficult to wet rock uniformly under realistic mining conditions, the optimum moisture content can be much higher.[5] The water used for dust suppression, particularly in drilling and in blasting, should be as clean as possible, because the evaporation of dirty water can also release dust.

Sufficient ventilation is critical for the control of blasting dust since water alone is usually inadequate. Blasting dust and fumes should be diluted quickly and exhausted to the surface[6] via an untraveled return route. If this is not possible, the common practice is to arrange the blasting schedule so that the contaminated air will pass through working places when the miners are absent.

CONVEYOR BELT DUST CONTROL

A conveyor belt can generate large amounts of respirable dust from several sources. If the belt is not clean, dust is knocked from the belt as it passes over the idlers. Belt scraping and washing will reduce this dust source, and if the belt is dry, just wetting it can help. Also, much respirable dust originates at belt transfer points.

Belt cleaning by scraping and washing. Conveyor belts are usually equipped with belt scrapers; some have belt washers as well. Several manufacturers sell scrapers and washers; these play an important role in reducing the amount of dust generated by conveyor belt carryback. Carryback is that portion of the carried material that sticks to the belt instead of falling off at the head pulley. It becomes airborne dust as the belt dries and passes over the return idlers. When dust levels are high, the usual approach is to add a second or even third scraper rather than trying to get a single scraper to work better.

While multiple scrapers will reduce dust, they may be more efficient at spillage control than respirable dust control. Roberts et al. [1987] have shown that with each successive scraping, both the percentage of fines and the moisture level of the carryback substantially increase. This

[4]Weight of water in the rock divided by the weight of rock.

[5]Quilliam [1974] recommends 5%, but this seems high to us.

[6]Much of the dust will be deposited in the return airways. For example, Ford [1976] found that 45% of a 4-µm particle size dust cloud was deposited within a distance of 600 ft. Bhaskar et al. [1988] measured 38% deposition of respirable dust at air velocities over 300 ft/min and 67% deposition at an air velocity of 165 ft/min. Stachulak et al. [1991] measured a 66% decrease in respirable dust in a 500-ft vertical return air raise.

shows that the larger material is preferentially removed by scraping and the smallest fines (which generate respirable dust) tend to stay stuck to the belt.

If multiple scrapers do not remove enough carryback to cut the respirable dust sufficiently, a water wash system may be necessary. These systems spray the belt with water in addition to scraping it. Stahura [1987] has written a comprehensive discussion of conveyor belt washing. Planner [1990] has reported on the average belt-cleaning efficiency of water sprays when used with primary and secondary scrapers. In the Planner study, water sprays placed between the primary and secondary scrapers reduced carryback from 11.1% to 3.4%. In another test, water sprays added to a secondary scraper reduced carryback from 13.9% to 1.1%.

Belt sprays also reduce airborne dust. Rodgers et al. [1978] added a 150-gpm water spray system to dry scrapers on a 54-in belt at a taconite processing plant. The sprays reduced respirable dust by 48% and total dust by 78% compared to dry scrapers alone. More recently, Baig et al. [1994] reported that airborne (respirable and float) coal dust levels were reduced 80%-90% when their belt scrapers were augmented with spray wash boxes.

Wetting of dry belts. Several studies have shown that wetting the bottom (return) belt can reduce dust from a dry belt. For example, Courtney [1983] measured the respirable dust reduction from a single 0.33-gpm spray onto the top surface (the noncarrying surface) of the bottom belt. The goal was to prevent dust from being knocked loose by the tail pulley and upper idlers. The spray was followed by a piece of ordinary floor carpet that wiped the belt to prevent channeling of the water. The spray and carpet were mounted close to the tail pulley so that the belt was wet as it passed around the tail pulley and moved outby over the upper idlers (figure 6-2).

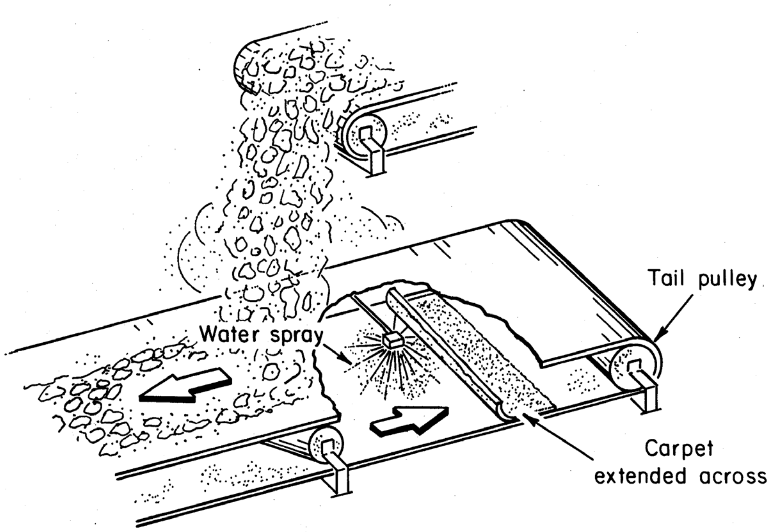

Figure 6-2.—Wetting the top surface of the bottom belt.

Respirable dust reduction from installation of the spray and carpet averaged 75%. A 2-gpm spray without the carpet worked about as well. Slippage from excessive wetting was not a problem, as water usage was low (only 2 gpm) and the belt then traveled for 5,000 ft before passing over the drive at the head end.

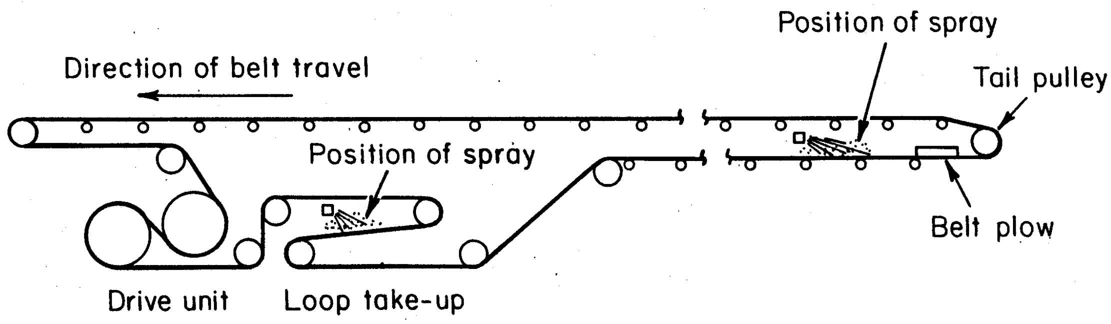

Figure 6-3.—Wetting both surfaces of the bottom belt.

A decade earlier than Courtney, Ford [1973] tested a system that wetted both surfaces of the bottom belt (figure 6-3). A spray in the loop take-up near the belt head wetted the carrying surface so that dust was not knocked loose by the ingoing trip over the lower idlers. Then, near the tail pulley, the noncarrying surface of the bottom belt was wetted by a second spray for the trip around the tail pulley and across the upper idlers, similar to the system described by Courtney. Sprays were mounted so as to wet the entire width of the belt, and they were controlled automatically to operate only when the belt ran. A belt plow was used in place of the carpet. Respirable dust was reduced by 67% with a total (all sprays) water flow of 0.53 gpm.[7]

TRANSFER POINT AND CRUSHER DUST CONTROL

Transfer points. The traditional approach to transfer point dust control is to tightly enclose the transfer point, exhaust the dust-laden air from the enclosure through a duct, and either remove the dust from the air with a dust collector or discharge the dust to a return airway (figure 6-4).

Transfer point dust control can be difficult because the falling rock has a "piston effect" due to air entrainment. This air entrainment draws mine air in at the top of the transfer point enclosure, and it can push dusty air out of the bottom of the enclosure. The piston effect of the falling rock can be reduced by lowering the drop distance, by using "rock ladders" to break the fall of the rock, and by increasing the enclosure size so that entrained air can circulate back to the top of the enclosure. Tight enclosure of the transfer point requires adjustable skirtboard sealing systems, a means to prevent belt sag in the loading zone, and careful sealing of belt entry and exit locations, among others. The usual airflow guideline is to plan for 200 (or more[8]) ft/min air velocity through all unavoidable openings.

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[7]Low-flow spray nozzles are prone to clogging because of their small orifice size. To avoid nozzle clogging while reducing water use, control timers have been developed to cycle belt sprays on and off (BWI Eagle, Inc.). Timers also allow better control over the degree of belt wetting.

[8]MAC [1980] recommends adding 25% to the 200 ft/min as a safety factor. Yourt [1969] recommends that if a loaded belt is leaving the enclosure the air velocity be set at 200 ft/min plus the belt speed to counteract the drag effect. For instance, if the belt speed is 300 ft/min, then the air velocity into all unavoidable openings should be 500 ft/min. Rodgers [1974] gives a rule of thumb of 700-800 cfm of exhaust ventilation per foot of belt width.

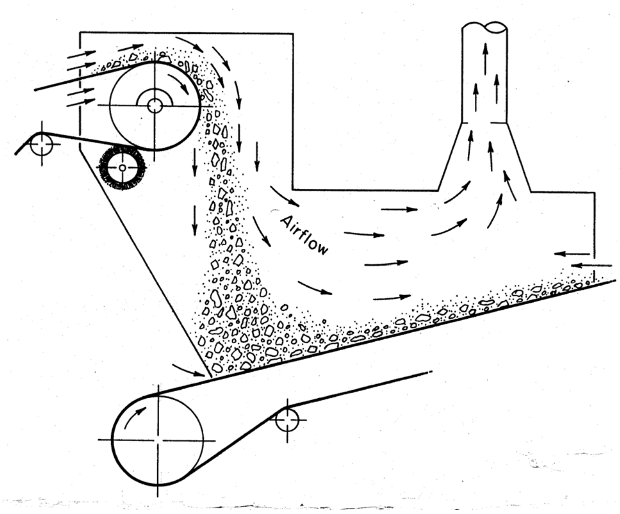

Figure 6-4.—Dust-laden air exhausted from transfer point enclosure.

Duct takeoffs from transfer point (and crusher) enclosures must be designed to avoid picking up large particulate. The Mining Association of Canada [MAC 1980] recommends that the takeoff air duct be at least 6 ft from the falling rock to avoid picking up particles. Yourt [1969] suggests that the base of the takeoff cone be large enough so that the velocity of air exhausted is 500 ft/min or less.

In addition to proper design of takeoffs, the ductwork leading to the dust collector or return airway must be designed to prevent dust settling. Yourt [1969] suggests that risers be installed at a steep angle, not less than 58º, and that horizontal runs be sized for a velocity of at least 3,000-3,500 ft/min. ACGIH [2001] suggests a velocity of 3,500-4,000 ft/min. Cleanout ports should always be provided in horizontal ductwork.

Another way to reduce dust at transfer points is to provide an enclosed sliding chute to transfer the material. Sliding chutes and spouts are widely used in materials handling; much information on them is available [Page 1991; Mody and Jakhete 1987].

There is a wealth of information on how to reduce transfer point dust [MAC 1980; Goldbeck and Marti 1996; Swinderman et al. 1997; Mody and Jakhete 1987; Yourt 1969; ACGIH 2001; Organiscak et al. 1986].

Crushers. Crushers in mines range from small roll types used in coal mines to large cone types used in hard-rock mines and mills. Whatever the size and method of crushing, dust is controlled by water sprays and local exhaust ventilation from the crusher enclosure. The amount of water needed is hard to specify. It depends on the type of material crushed and the degree to which water will cause downstream handling problems. If the rock is dry, a starting point is to add a water quantity equivalent to 1% of the weight of the material being crushed [Quilliam 1974].

Crushers need lots of air and lots of water because they break lots of rock.

The amount of air required depends on how much the crusher can be enclosed. Enough air should be exhausted from a plenum under the crusher to produce a strong indraft at the jaw, grizzly, and any other openings around the crusher. The design guidelines for determining the required airflow are the same as those for transfer points. The unavoidable open area is calculated and multiplied by a 200 ft/min indraft velocity.[9] The required airflow is usually large. For example, Rodgers et al. [1978] have described how dust from a 5-ft cone crusher was reduced by using a 75,000-cfm[10] exhaust ventilation system and a control booth for the operators.[11] Yourt [1969] has given a comprehensive set of design principles for dust control at crushing and screening operations. If there is an ore pass above the crusher, precautions should be taken to ensure that it is not pulled empty.

If the crusher can be located in a short, dead-end (stub) heading, then air can be drawn into the crusher in the usual way and then discharged from the heading through ductwork. This design approach creates an air movement into the stub heading that confines any dust that escapes the crusher.[12]

MAC [1980], Walker [1961], Phimister [1963], and Ahuja [1979] have described dust control methods used for large crushers at underground locations. Foam is also used to control dust at crushers, particularly where water use must be limited. Use of foam is described in chapter 1 on dust control methods.

VENTILATION OF PRODUCTION AREAS

Production areas are ventilated by directing an air split from the main ventilating stream through the workings. Sandys and Quilliam [1982] have recommended that a minimum air velocity of 100 ft/min is needed to remove mineral dust in headings where track- and tire-mounted loaders are used for mucking ore. Dust generated by moving equipment can be reduced by applying water or chemicals (most commonly hygroscopic salts) to the roadways.[13]

However, if enough air is supplied to meet the requirements of the diesel equipment in the heading, then the mineral dust is well controlled. The usual diesel airflow criterion has been to supply 100-125 cfm per horsepower of diesel equipment, all equipment being cumulative in any one split.

> **New MSHA regulations on diesel particulate, enacted in 2001, will require even more air in U.S. mines unless the particulate level can be reduced by other means.**

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[9]Plus a 25% safety factor [MAC 1980]. See also footnote 8.

[10]Large air quantities may be required because falling rock induces its own airflow. Pring [1940] investigated the amount of air required to produce an indraft in surge bins at crusher installations. About 35,000 cfm was required at a large crusher installation.

[11]If large (80% or more) dust reductions are sought for workers near a crusher, the most practical way to achieve this is to provide an enclosed and pressurized control booth supplied with filtered air.

[12]The benefits of locating a crusher in a stub heading are explained in more detail in chapter 4 on stone mines.

[13]Reduction of roadway dust is discussed at greater length in chapter 5 on surface mines.

Stachulak [1989] has pointed out that, not long ago, 10,000 cfm[14] was adequate for most development headings. However, some mines are now driving single drifts requiring 80,000 cfm to meet legal requirements for the diesel equipment.

In development headings, a blowing system kept to within 100 ft of the face will usually provide a satisfactory dust level. Exhaust systems can do a good job of removing dust when the end of the duct is held within 10 ft of the dust source. However, keeping a 10-ft distance can be difficult in development headings because of potential blast damage to the duct.

ROADHEADER DUST CONTROL

Roadheaders are occasionally used in hard-rock mines, but they are also used in many other underground excavations, from tunnels to wine storage caves. They have a reputation for generating dust for several reasons. Headings excavated by roadheaders are often larger in cross-section, and it can be hard to supply enough ventilation air to confine the dust cloud at the face. Some aspects of roadheader design also contribute to dust buildup. The cutting boom is narrow, so there is little of the dust cloud confinement provided by a wide boom. Also, the operator compartment is sometimes located far forward where the dust is inevitably higher. Finally, remote control of the machine, the best way to deal with dust, may not be available.

Dust control methods for machines like roadheaders usually depend on some degree of dust cloud confinement. In mines where methane is released along with the dust, confining the dust cloud will raise the methane concentration.

Below are the various methods used to control roadheader dust, assuming that the material being excavated generates no methane gas.[15]

Ventilation-based controls. For a ventilation-based dust control, provide an adequate air volume using an exhaust duct with the duct inlet located close to the face. The volume should be sufficient to provide a forward air velocity in the heading of at least 60 ft/min based on the cross-sectional area of the empty heading. The duct inlet should be at least 10 ft forward of the operator and within 5 ft of the face.[16] Decreases in the air volume and increases in the duct inlet distance can have a big effect on dust levels (figure 6-5) [Ford and Hole 1984].

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[14]The usual guideline was 50 cfm per square foot of face area, equal to a velocity of 50 ft/min.

[15]Lowering spray pressures will reduce the air turbulence. When air turbulence is reduced, methane concentration levels may rise. When a half-curtain is used at a gassy face, methane can build up behind the curtain. A good discussion of roadheader dust control, both with and without methane, is in Hole and Belle [1999].

[16]These recommended air velocities and duct distances are target values based on average conditions, assuming that remote control is not used. If a mine is under more stringent standards because of silica in the dust, more air may be needed.

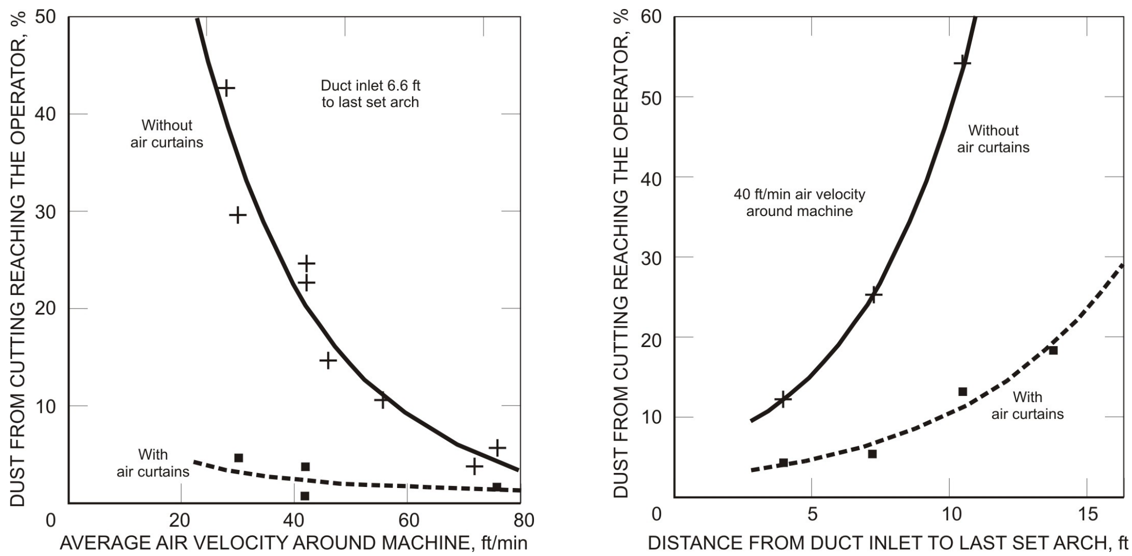

Figure 6-5.—Effect of duct inlet position, air velocity, and air curtain use on dust levels (from Ford and Hole [1984]).

The second step in ventilation-based dust control is to locate and use water sprays so as to minimize air turbulence at the face. High-pressure sprays or nozzles located to spray out into the open air will produce air turbulence. This turbulence will cause the dust cloud to expand and back up (rollback) against the ventilation air, covering the machine operator [Hole and Belle 1999]. To minimize turbulence, the water sprays on the boom should be located close to the cutting head to wet only the cutting head and the broken rock falling down from it. The water pressure (as measured at the spray nozzles) should be limited to 100 psi or less. If more water must be applied, larger orifice nozzles should be used. If the rock on the gathering pan must be wetted, only high-volume, low-pressure nozzles should be used. Finally, in headings where the cross-sectional area (not counting the machinery) is over 100 ft^2, a half-curtain should be considered in order to raise the air velocity for better dust confinement. Dust rollback and use of a half-curtain are explained more fully in chapter 1 on dust control methods.

Machine-based controls. Three machine-based controls are available to lower roadheader dust. First and most important is remote control. In conjunction with exhaust ventilation, remote control of the roadheader allows the machine operator to step back away from the dust cloud at the cutting face. In most cases, it is the most effective way to lower the operator's dust level.

The second control is to use a wet-head machine with low-pressure sprays. Several research studies have shown that wet heads will yield moderate dust reductions. The downside of wet heads is that the sprays can produce turbulence that causes the dust cloud to expand and roll back against the ventilation air, covering the machine operator with dusty air. For this reason, the nozzle pressure should be held below 50 psi. Hole and Belle [1999] report that a roadheader wet head operating at 20 psi and 6 gpm gave a 40% dust reduction compared to external sprays.

The third machine-based dust control is to use a Coanda air curtain to hold the dust cloud against the cutting face and away from the operator. Air curtains for dust control were devised in Germany and the United Kingdom. They are available as an option on some new machines. The greatest benefit is obtained when the ventilation quantity is low and the exhaust duct inlet cannot be held close enough to the cutting face. In underground testing, dust rolling back from the face was reduced by 80% when air curtains were used[17] (figure 6-5) [MRDE 1983; Hole and Belle 1999].

The best way to approach roadheader dust control will depend on individual circumstances. Providing sufficient airflow, keeping the exhaust duct inlet close to the cutting face, and using remote control will normally be sufficient to control dust. However, sufficient airflow and remote control are not always available. Keeping the duct inlet close to the face subjects it to damage by the cutter head. Therefore, if these conventional ventilation and remote-control remedies cannot be used, a half-curtain should be tried. Also, it might be possible to cut the face in two steps, first on the duct side, after which the duct is moved forward, and then the other side. Diligent replacement of worn picks can always help as well.

If all else fails, the operator of the roadheader should have a respirator or a fully enclosed cab that is equipped with an air filtration system. Cabs with filtration systems are discussed in chapter 5 on surface mines. Dust respirators are discussed in chapter 9.

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